Malays. Appl. Biol. (2022) 51(4): 137-144
https://doi.org/10.55230/mabjournal.v51i4.22

DIVERSITY AND DISTRIBUTION OF CLASS INSECTA FROM SELECTED AREA OF TUBA ISLAND RESERVE FOREST

SITI KHAIRIYAH MOHD HATTA[1,2*], NURSYAFIEZA RUSIDILBUKHARI[1], NUR NADIAH MD YUSOF[1], NORASHIRENE MOHAMAD JAMIL[1], KAMARUL HAMBALI[3], NOOR AKMAL ABD WAHAB[4], SITI NOORFAHANA MOHD IDRIS[4], NORHAFIZAH MOHD ZAZI[4] and FAEZAH PARDI[1,5]

[1]*Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia*
[2]*Sustainable Crop Protection Research Group, Universiti Teknologi MARA, 40450, Shah Alam*
[3]*Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia*
[4]*Centre of Foundation Studies, Universiti Teknologi MARA (Dengkil Campus), 43800 Dengkil, Malaysia*
[5]*Institute for Biodiversity and Sustainable Development, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia*
[*]*E-mail: sitikhairiyah@uitm.edu.my*

Accepted 3 October 2022, Published online 31 October 2022

ABSTRACT

Insects are ubiquitous and inhabit all types of ecosystems that include island ecosystems. A study on the diversity and distribution of Class Insecta was conducted at a selected forest area in Pulau Tuba using malaise traps. No insect study has been conducted at Pulau Tuba before. Three study sites namely forest fringe, middle forest, and inner forest were chosen. A total of 5883 specimens belonging to seven orders and 106 morphospecies of insects were collected. The orders identified were Blattodea, Coleoptera, Diptera, Hymenoptera, Hemiptera, Isoptera, and Lepidoptera. Diptera samples were the most found while Blattodea recorded the lowest number recorded. Shannon-Wiener Diversity Index (H') showed that the inner forest had the highest diversity value with H' = 0.53, followed by the forest fringe with H' = 0.44, and the middle forest with H' = 0.22. The Evenness Index (E') and Margalef Richness Index (R') also showed the highest value comes from the inner forest with E' = 0.28 and R' = 0.81 respectively. Kruskal-Wallis test showed that there was a significant difference in insect distribution across three study sites where $P< 0.05$. Overall, this study suggested that the diversity of Class Insecta at Pulau Tuba was low in the three locations confirming the low species richness of insects in the island forest ecosystem.

Key words: Abundance, diversity, diversity indices, insects, island forest

INTRODUCTION

The tropical rainforest is one of the most diverse ecosystems on earth as they hold the habitats for various types of plants, animals, and microorganisms species. One of the subsections of tropical rainforests is the tropical island forest. This closed island ecosystem is usually associated with high endemism but a moderate level of species diversity (Kier *et al*., 2008). A high level of endemism occurs due to the development of distinct genetic reservoirs and the occurrence of highly specialized species caused by the isolation of islands over geological time (Sivaperuman *et al*., 2008). It the unique in its biodiversity and physical environment often subjected to various natural and anthropogenic issues (Sivaperuman *et al*., 2008). The simple interaction between organisms in the island ecosystem governed by local selection pressure makes them susceptible to any pressure (Samways *et al*., 2010). Assessing the biodiversity of flora and fauna in island ecosystems can serve as a model system for biodiversity conservation (Russel & Kueffer, 2019) and is crucial in making policies and any management plan to sustain the tropical island forest organisms (McGinley *et al*., 2019).

Insects (Class Insecta) are ubiquitous components in the environment including terrestrial and freshwater by being a part of food webs but have the least portion of cumulative biomass compared to plants and microbes (Yang & Grattan, 2014). Their morphologically small size, primarily allows them to inhabit more habitats and niches compared to the larger fauna (Mohd Pudzi *et al*., 2017). Class Insecta are classified into 30 orders with eight dominant orders (Campbell, 2020). Insect diversity makes up three-quarters of all species and they have been hugely successful in terms of species richness and abundance (Samways (2005). The four major orders of these diverse species are Coleoptera (beetles), Lepidoptera (moths and butterflies), Hymenoptera (sawflies, ants, bees, and wasps), and Diptera (true flies) (Jarzembowski, 2021)

* To whom correspondence should be addressed

where Hymenoptera is known to be the largest order of insects (Forbes *et al*., 2018).

The distribution of insects is influenced by abiotic and biotic factors. Temperature gives a huge influence on species richness and evenness of insects more than habitat (Corcos, *et al*. (2018). Elevation also plays a huge role in insect distribution where low elevation is often associated with more diverse insect taxa (Siti Khairiyah *et al*., 2013; Cuartas-Hernández & Gómez- Murillo, 2015; Mohd. Pudzi, *et al*., 2017). Other abiotic factors that influenced the distribution of insects are light intensity (Eo *et al*., 2009) and precipitation (Chen *et al*., 2019). Biotic factors like the number of vegetation (Siti Khairiyah *et al*., 2013), types of vegetation (de Cauwer *et al*., 2006), types of tree crown (Gossner, 2009), and relationship with predators shaped the distribution of insect communities.

Tuba Island is one of 99 islands in the Langkawi archipelago encompassing natural forest and a distantly located nearby island, both having more or less similar common macroclimatic conditions. This island is called "Tuba" because of a native plant species named the Tuba plant that can be found abundantly on this island (Majlis Perbandaran Langkawi Bandaraya Pelancongan (MPLBP), 2020). Tuba Island is a part of Dayang Bunting Geoforest Park. The functions of Geoforest park are to preserve geodiversity and biodiversity in diverse habitats including mangroves, tidal flats, beaches, estuaries, coral reefs, caves, limestone, and other various life in those areas (Rahmah, 2017). Of all 99 islands in The Langkawi archipelago, only six islands are inhabited namely, Langkawi (the main island), Tuba, Dayang Bunting, Bidan, Song-song, and Bidang (Mohd Yusof *et al*., 2014; Hashim *et al*., 2015).

Tuba Island is a well-known island for having a diverse scenic landscape that includes mountains, forests, and coastal ecosystems within a small island and this demanded the intensification of tourism activities (Othman & Kamarudin, 2016). Significantly modified Malaysia's terrestrial landscapes and is one of the biggest drivers of biodiversity loss, habitat fragmentation, and pollution.

This study aims to assess insect diversity and distribution in an island ecosystem. This study also compares insect distribution across the environmental gradient from the forest fringe to the inner forest of the island ecosystem. Until today, study is absent on the diversity and abundance of class Insecta conducted in Tuba Island, Langkawi. Thus, this research is seen as an initial approach to creating the first components of a faunal inventory on the ecology of Tuba Island. Insects react to changes in environmental factors quickly and rapidly (Schowalter *et al*., 2018) enabling them to act as indicators of forest conditions for decades (Arnan *et al*., 2010). Due to high sensitivity and fast reaction, it also helps to understand the response of species to changes in both biotic and abiotic factors (Menéndez *et al*., 2014). Such studies could be used to conserve island ecosystems and their special biological features as well as assist in the control and protection of likely future biodiversity losses (Whittaker & Fernández-Palacios, 1998; Foottit & Adler, 2009).

MATERIALS AND METHODS

Study site

Tuba Island is located five kilometers Southwest of Kuah-Jetty Langkawi and it takes about 15 to 20 min to Tuba Island by boat. This island has an area of 1,724 ha (Langkawi Development Authority (LADA), 2019). The collection of samples was taken from the conservative forest near Bukit Puteh and Gua Kelawar which are popular destinations for tourists (Figure 1).

Sampling methods

Malaise traps (Figure 2) were used to sample the insects starting from the forest fringe to the inner forest. The traps were separated from each other by about 100 m (Figure 3). Trap 1 represents the forest fringe; Trap 2 represents the middle forest and Trap 3 represents the inner forest. A Census line was set up from the forest fringe towards the inner forest to study the distribution across environmental gradients.

The traps were placed along the census line. Malaise trap with collecting bottle or killing bottle attached at the top of the trap and the killing bottle was filled with one-third of 70% ethanol (as in Upton & Mantle, 2010). The traps were left unattended for 5 days before being dismantled and the bottles were closed.

Data analysis

The collected insects are brought to the lab before being dried, pinned, labeled, and identified using a reference book with the key identification. The number of species diversity, species evenness, and species richness were analyzed using a statistical program (PAST) and the Kruskal Wallis test with pairwise comparison was conducted to see the mean differences in the distribution of insects at three different plots.

RESULTS AND DISCUSSION

The abundance of class Insecta orders in a selected forest area on Tuba Island

A total of 5883 insects from seven orders and 106 morphospecies were collected at Tuba Island, Langkawi. The orders collected were Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, and Lepidoptera (Figure 4). The most abundant order collected with 92.64% of individuals was Order Diptera, followed by Lepidoptera (1.43%), Coleoptera (0.90 %), Isoptera (0.17) and Blattodea

Fig. 1. The map of study sites on Tuba island. (source: Google Earth)

Fig. 2. Malaise trap.

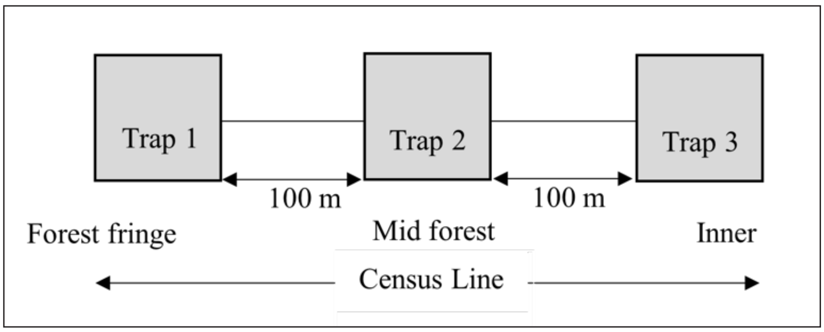

Fig. 3. The placement of malaise traps on the census line.

recorded in less than 10 individuals making it the least order recorded (0.10%).

A high number of insects collected despite a short duration of sampling is due to the usage of malaise traps. This trap is the most effective trap to collect insects compared to other traps such as pitfalls, light traps, Berlese funnels, and sweep nets (Fraser *et al*., 2008). Diptera dominated the insect collection because most Dipteran species collected came from gnats families that were always associated with swarms, thus contributing to the higher number of individuals collected. Gnats usually swarm toward the white surface (Chiang, 1961) and this situation is expected since the malaise trap used is white color. The gnats depend on water to lay their eggs where their larvae develop including in pools, rain gutters, or even wet soil, and expected to be more after rains (Townsend, 2018) eggs and the rainy season during the sampling strengthened the high number of this Diptera. Diptera is also one of four dominant insect orders apart from Coleoptera, Hymenoptera, and Lepidoptera (Footit & Adler, 2009).

Only three percent of Hymenoptera (150 individuals) were collected in this study, regardless of the more than 100 000 described species of this order worldwide (Mason & Huber, 1993). A similar study on Hymenoptera abundance on the main island of Langkawi recorded 640 specimens from two different mountains (Siti Khairiyah *et al*., 2015). The fact that the duration of the study is longer than this present study together with a greater number of traps installed might be the reason for the difference.

Blattodea recorded the least order found in this study. Most literature on this minor order is based on their roles as pests in human-dominated habitats where this pest only encounters less than 1% of described species (Shahraki *et al*., 2013). Blattodea constitutes about 24% of arthropod biomass in tropical tree canopies worldwide (Basset, 2001). However, the reason behind the low number recorded in this study was not investigated.

The abundance of insect orders at different traps

The distribution of orders between traps showed Trap 1 recorded the highest number of total individuals of insects which were 2817 insects, followed by Trap 2 with 2592 individuals of insects, and Trap 3 has 474 total individuals of insects (Table 1).

The most abundant order was Diptera with a total of 5450 individuals where 2549 individuals were found in Trap 1, 2488 individuals were collected in Trap 2, and a total of 413 individuals were recorded in Trap 3. Order Diptera can be found in various kinds of habitats, but mostly they live near water sources such as streams, lakes, temporary puddles, ponds, and brackish and alkaline water (Donald *et al*., 1989). The rainy season during sampling creates puddles and this might attract the flies and mosquitoes to inhabit the study sites during the sampling duration.

A total of 106 morphospecies were collected in

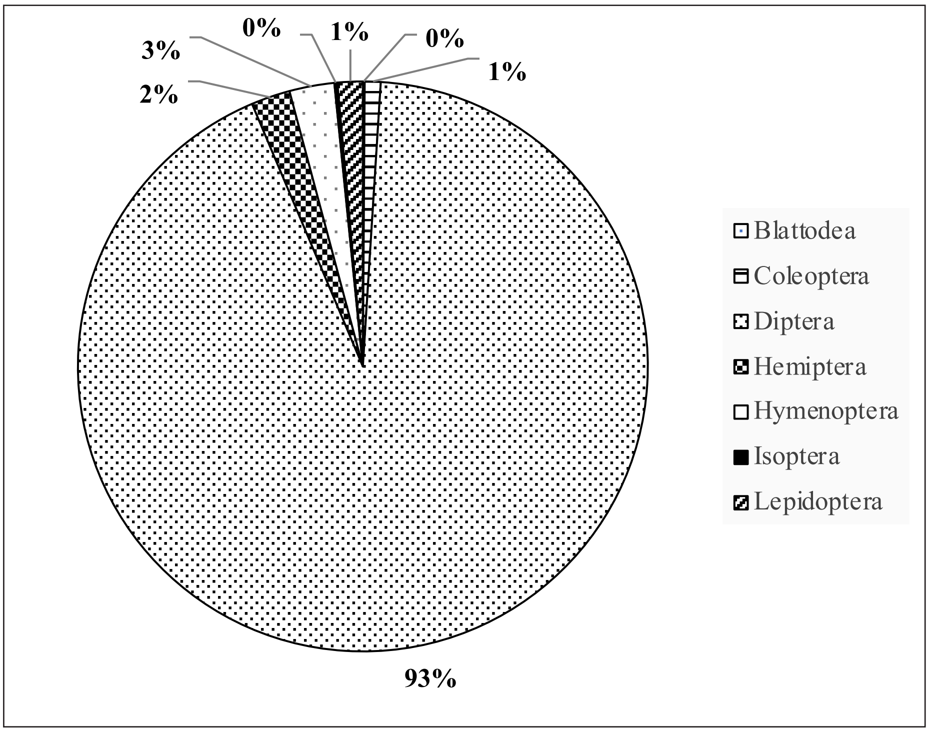

Fig. 4. The orders of Class Insecta collected at Tuba Island.

Table 1. Number of insect orders in different traps

Order	Morphospecies	Traps			Total individual
		1	2	3	
Diptera	27	2549(23)	2488(2)	413(2)	5450
Hymenoptera	32	66(27)	48(2)	36(3)	150
Hemiptera	12	111(11)	10(1)	9(1)	130
Lepidoptera	19	52(7)	27(9)	5(3)	84
Coleoptera	13	33(9)	10(3)	10(1)	53
Isoptera	2	0	9(2)	1(1)	10
Blattodea	1	6(1)	0	0	6
Total individual		2817	2592	474	5883
		48%	44%	8%	
Total Order	7	6	6	6	
Total morphospecies	106	78	18	10	

(The value in the bracket is the total number of morphospecies among orders of Class Insecta at the study sites).

this study from a total of 5883 individuals collected. This study has a smaller number of species compared to a study on three islets in Nigeria from April to July 2009 with a total of 144 species and the highest island recorded 140 species (Aissat & Moulai, 2016). The most diverse order was Hymenoptera with 32 morphospecies, followed by order Diptera (27 morphospecies), Lepidoptera (19 morphospecies), Coleoptera (13 morphospecies), Hemiptera (12 morphospecies), Isoptera (two morphospecies), and Blattodea (one morphospecies) (Table 4.1). Hymenoptera in Tuba Island recorded fewer species from the main Langkawi archipelago with 46 species (Siti Khairiyah *et al*., 2015).

Trap 1 was located at the forest fringe where the number of vegetation is high. This diversity of vegetation provides a food source for most insect orders (Aissat & Moulai, 2016). A study at the oil palm plantation that planted a beneficial plant, *Tunera* sp. at the margin area recorded the highest insect collected, especially Diptera (Mohd Hanysyam., *et al*., 2013). A similar study by Mohd Hatta *et al*. (2015) also found Diptera and Orthoptera more diverse at the forest fringe while Hemiptera was diverse in the inner forest. Forest fringe is also more open where high light intensity is present thus attracting more insects (Gossner 2009).

Sampling collection was conducted during the first monsoon or known as the southwest monsoon. This monsoon is always associated with a flood, heavy rainstorms, and changes in wind speed or gusts (Lockard, *et al*., 2021). Raindrops cause in-flight distress to fly insects although some of them have adapted to reduce the impacts of the raindrops (Dickerson *et al*., 2012). Heavy rains can also cause low life expectancy and prevent movement within and between habitats (Pellegreno *et al*., 2013). Changes in the frequency of precipitation may affect the survival and development of insect herbivores (Chen *et al*., 2019).

Diversity of insect orders

The overall Shannon-Wiener Diversity Index (H') showed the diversity was higher in Trap 3 (H'= 0.53) compared to Trap 1 (H'= 0.44) and Trap 2 (H'= 0.22) even though the least number of individuals were collected here. The typical values of diversity are generally between 1.5 and 3.5 whereas, in most ecological studies, the index is rarely greater than 4 (Mohamed *et al*., 2019). Species richness and species evenness of the community contributed to the H' value where high numbers of both will lead to a high number of H' (Chung *et al*., 2016).

Evenness Index (E') measures give way to a specific interpretation of community organization and it ranges from zero to one, with one having a complete evenness in the area (Beisel *et al*., 2003). The value of E' for Trap 3 (E'= 0.28) was higher compared to Trap 1 (E'= 0.26) and Trap 2 (E'= 0.21). This explained that Trap 3 showed the least dominance of order compared to the other two traps. The low overall E' value in this study site is due to the higher number of Diptera individuals collected compared to the other orders.

Trap 1 and Trap 2 showed a similar value of Margalef Richness Index with R'= 0.63, while the R' value for Trap 3 was 0.81. This showed that Trap 3 has the highest R' value and this area has the highest species richness compared to Trap 1 and Trap 2. Even though the number of individuals collected in Trap 3 was less than the others, this trap recorded the highest number of morphospecies collected. The distribution of insect orders across the environmental gradient from the forest fringe to the inner forest differ significantly (Kruskal Wallis, χ^2=31.34, df=2, P<0.05) where the pairs contribute to the significance are from Trap 1 – Trap 2 and Trap 2- Trap 3. The orders are not significantly distributed between Trap 1 and Trap 3.

Table 2. Shannon-Wiener Diversity Index (H'), Evenness Index (E'), and Margalef Richness Index (R')

Trap	H’	E’	R’
Trap 1	0.44	0.26	0.63
Trap 2	0.22	0.21	0.63
Trap 3	0.53	0.28	0.81

CONCLUSION

The diversity of insects in the island ecosystem is indeed low. The sampling during the rainy season and fewer traps used might contribute to the results. Endemism is usually high in the island ecosystem however, it was not investigated in this study. Tuba Island is one of the Langkawi Archipelago which was awarded as the Global Geopark that functions to preserve the geodiversity and biodiversity of many florae, fauna, and ecosystems. This action is great to maintain and conserve our endangered and extinct animals and plants as well as to protect their habitat that is rich with endemic species.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Adnan and Mr. Fazlan for assisting in collecting the samples. Special thanks also go to Jabatan Perhutanan Negeri Kedah for permitting us to conduct this study. This research has been funded by the Universiti Teknologi MARA under grant number 600-RMC/LESTARI SDG-T 5/3 (168/2019).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Aissat, L. & Moulai, R. 2016. Analysis of Insect Diversity of Three Islets in the North-East of Algeria. *Journal of the Entomological Research Society*, **18(2)**: 01-21.

Arnan, X., Bosch, J., Comas, L., Gracia, M. & Retana, J. 2010. Habitat determinants of abundance, structure and composition of flying Hymenoptera communities in mountain old-growth forests. *Insect Conservation and Diversity*, **4**: 200-211.

Basset, Y. 2001. Invertebrates in the canopy of tropical rain forests—How much do we know? *Plant Ecology*, **153**: 87-107. https://doi.org/10.1023/A:1017581406101

Beisel, J.N., Usseglio-Polatera, P., Bachmann, V. & Moreteau, J.C. 2003. A comparative analysis of evenness index sensitivity. *International Review of Hydrobiology*, **88(1)**: 3–15. https://doi.org/10.1002/iroh.200390004

Campbell, N.A., Urry, L., Cain, M.L, Wasserman, S.A., Minorsky, P.V. & Orr, R.B. 2020. *Biology: A Global Approach*. Global Edition (Twelfth Ed.). United State: Pearson. 766 pp

Chen, C., Harvey, J., Biere, A. & Gols, R. 2019. Rain downpours affect survival and development of insect herbivores: The spectre of climate change? *Ecology,* **100(11)**: e02819. https://doi.org/10.1002/ecy.2819

Chiang, H. C. 1961. Ecology of insect swarms. I. Experimental studies of the behaviour of Anarete near felti pritchard in artificially induced swarms (Cecidomyiidae, Diptera). *Animal Behaviour*, **9(3-4)**: 213–219. https://doi.org/10.1016/0003-3472(61)90011-2

Chung, A., Bosuang, S., Majapun, R. & Nilus, R. 2016. Diversity and Geographical Ranges of Insects in Crocker Range Forest Reserve, Sabah, Malaysia. *Journal of Tropical Biology and Conservation*, **13(1)**: 136-155.

Corcos, D., Cerretti, P., Mei, M., Vigna Taglianti, A., Paniccia, D., Santoiemma, G., De Biase, A. & Marini, L. 2018. Predator and parasitoid insects along elevational gradients: role of temperature and habitat diversity. *Oecologia,* **188(1)**: 193-202. https://doi.org/10.1007/s00442-018-4169-4

Cuartas-Hernández, S.E. & Gómez-Murillo, L. 2015. Effect of Biotic and Abiotic Factors on Diversity Patterns of Anthophyllous Insect Communities in a Tropical Mountain Forest. *Neotropical Entomology,* **44**: 214–223 https://doi.org/10.1007/s13744-014-0265-2

de Cauwer, B., Reheul, D., De Leethauwer, S., Nijs, I. & Milbau, A. 2006. Effect of light and botanical species richness on insect diversity. *Agronomy for Sustainable Development*. **26**: 35-43. https://doi.org/10.1051/agro:2005058

Dickerson, A.K., Shankles, P.G., Madhavan, N.M. & Hu, D.L. 2012. Mosquitoes survive raindrop collisions by virtue of their low mass. *Proceedings of the National Academy of Sciences*, **109 (25)**: 9822-9827. https://doi.org/10.1073/pnas.1205446109

Donald, J.B., Charles, A.T. & Norman, F.J. 1989. An Introduction to the Study of Insects. Sixth Ed. Saunders College Pub. Philadelphia. 875 pp.

Eo, J., Kim, M.H., Na, Y.E., Oh, Y.J. & Park, S. 2017. Abiotic effects on the distributions of major insect species in agricultural fields. *Entomological Research*, **47(3)**:160–166. https://doi.org/10.1111/1748-5967.12207

Fraser, S.E., Dytham, C. & Mayhew, P.J. 2008. The effectiveness and optimal use of Malaise traps for monitoring parasitoid wasps. *Insect Conservation and Diversity*, **1**: 22–31.

Forbes, AA., Bagley, R., Beer, M., Alaine, C.H. & Heather, W. 2018. Quantifying the unquantifiable: Why Hymenoptera, not Coleoptera, is the most speciose animal order. *BMC Ecology*, **18(21)**. https://doi.org/10.1186/s12898-018-0176-x

Foottit, R.G. & Adler, P.H. 2017. Insect Biodiversity: Science and Society. 2nd Ed. Wiley Blackwell. 912 pp.

Gossner, M.M. 2009. Light intensity affects spatial distribution of Heteroptera in deciduous forests. *European Journal of Entomology*, **106(2)**: 241-252. https://doi.org/10.14411/eje.2009.032

Hashim, R., Latif, Z.A., Merican, F.M. & Zamhury, N. 2015. The Praxis of Langkawi's Sustainable Regeneration Strategy through Eco-tourism. *Procedia - Social and Behavioral Sciences*, **170**: 49–57. https://doi.org/10.1016/j.sbspro.2015.01.014

Jarzembowski, E.A. 2021. Fossil insects 10 years after the geological conservation review (Great Britain). *Palaeoentomology*, **004(4)**: 313–318.

Kier, G., Kreft, H., Lee, T., Jetz, W., Ibisch, P., Nowicki. C., Mutke, J. & Barthlott, W. 2009. A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Sciences of the United States of America*, **106(23)**: 9322-9327. https://doi.org/10.1073/pnas.0810306106

Langkawi Development Authority (LADA). 2019. Our Four Wonders – Langkawi Geopark. [WWW Document]. URL https://langkawigeopark.com.my/geoforest-park (accessed 7.7.2019).

Lockard, C., Ahmad, Z., Bee, O.J. & Leinbach, T. 2021. Malaysia. [WWW Document]. URL https://www.britannica.com/place/Malaysia (accessed 1.7.22).

Majlis Perbandaran Langkawi Bandaraya Pelancongan (MPLBP). 2020. Pulau Tuba. [WWW Document]. URL http://www.mplbp.gov.my/ms/pelawat/destinasi-menarik/pulau-tuba (accessed 1.20.22).

Mason, W.R.M. & Huber, J.T. 1993. Hymenoptera of the World: An Identification Guide to Families. Ottawa, Canada. 4-6 pp.

McGinley, K.A., Robertson, G.C. & Friday, K.S. 2019. Examining the sustainability of tropical island forests: Advances and challenges in measurement, monitoring, and reporting in the U.S. Caribbean and Pacific. *Forests*, **10**: 946. https://doi.org/10.3390/f10110946

Menéndez, R., González-Megías., Jay-Robert, P. & Marquéz-Ferrando, R. 2014. Climate change and elevational range shifts: evidence from dung beetles in two European mountain ranges. *Global Ecology and Biogeography*, **23(6)**: 646-657.

Mohamed, S., Zamri, K.M., Zullkeflee, A., Sajili, M.H., Roseli, M. & Mahmud, K. 2019. Insects diversity and abundance in coastal and inland forest of Perhentian Island, Terengganu, Peninsular Malaysia. *Bioscience Research*, **16(SI)**: 53–58.

Mohd Hanysyam, M.N., Siti Khairiyah, M.H., Fauziah, I., Fairuz, K., Mohd Rasdi, Z., Nurul Zfarina, M.Z., Ismail, R. & Norazliza, R. 2013. Assessment on the diversity of parasitoids of bagworms (Lepidoptera: Psychidae) in FELDA Gunung Besout 6, Sungkai, Perak. *2013 IEEE Symposium on Humanities, Science & Engineering Research,* 130-134.

Mohd Pudzi, S., Abd Aziz, N., Saiyid Shaifuddin, S., Abd. Ghani, I. & Mohd Hatta, S.K. 2017. The effect of elevation on diversity and abundance of Class Insecta at Gunung Datuk, Negeri Sembilan. *Serangga*, **22(2)**: 47-60.

Mohd Yusof, M.F., Ismail, H.N. & Raja Omar, R.N. 2014. A critical analysis on evolution of branding destination in Langkawi Island. *SHS Web of Conferences*, **12**: 01002. https://doi.org/10.1051/shsconf/20141201002

Othman, J. 2016. Ecotourism to sustain scenic beauty of Pulau Langkawi, Malaysia. *ILTC2016 Conference*.

Pellegrino, A.C., Peñaflor, M.F.G.V., Nardi, C., Bezner-Kerr, W., Guglielmo, C.G., Bento, J.M.S. & McNeil, J.N. 2013. Weather forecasting by insects: Modified sexual behaviour in response to atmospheric pressure changes. *PLoS ONE*, **8(10)**: e75004. https://doi.org/10.1371/journal.pone.0075004

Rahmah, R.A. 2017. Langkawi UNESCO Global Geopark (Malaysia). [WWW Document]. URL http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/list-of-unesco-global-geoparks/malaysia/langkawi/ (accessed 1.8.22).

Russell, C.C. & Kueffer C. 2019. Island biodiversity in the Anthropocene. *Annual Review of Environment and Resources*, **44**: 31-60. https://doi.org/10.1146/annurev-environ-101718-033245

Samways, M.J., Hitchins, P.M., Bourquin, O. & Henwood, J. 2008. Restoration of a tropical island: Cousine Island, Seychelles. *Biodiversity and Conservation*, **19(2)**: 425–434. https://doi.org/10.1007/s10531-008-9524-z

Schowalter, T.D., Noriega, J.A. & Tscharntke, T. 2018. Insect effects on ecosystem services-Introduction. *Basic and Applied Ecology*, **26**:1-7. https://doi.org/10.1016/j.baae.2017.09.011

Shahraki, G.H., Parhizkar, S. & Nejad, A.R. 2013. Cockroach infestation and factors affecting the estimation of cockroach population in urban communities. *International Journal of Zoology*, 1-6.

Siti Khairiyah, M.H., Usman, S., Suzita, Y., Florinsiah, L. & Nur Shahirah, N. 2013. The effect of elevations on diversity and abundance of class insecta at Taman Negara Gunung Ledang, Johor. *BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium*, **1**: 246–250. https://doi.org/10.1109/BEIAC.2013.6560125

Siti Khairiyah, M.H., Siti Noorfahana, M.I., Norhafizah, M.Z., Noorakmal, A.W. & Nur Syahidah, H. 2015. Species diversity and abundance of Hymenoptera; Ichneumonidae at selected forest in Langkawi Islands, Malaysia. *Advances in Environmental Biology*, **9(19 S4)**: 1–4.

Sivaperuman, C., Velmurugan, A., Singh, A.K. & Jaishankar. 2018. Biodiversity and climate change adaptation in tropical islands. First Ed. Academic Press, London. 31-51 pp

Townsend, L. 2018. Expect midges and gnats after rains. Morning Ag Clips. https://www.morningagclips.com/expect-midges-and-gnats-after-rains/

Upton, M.S. & Mantle, B.L. 2010. Methods for Collecting, Preserving and Studying Insects and Other Terrestrial Arthropods. Fifth Ed. Australian Entomological Society Miscellaneous Publication. 83 pp

Yang, L.H. & Grattan, C. 2014. Insects as drivers of ecosystem processes. *Current Opinion in Insect Science*, **2**: 26-32. https://doi.org/10.1016/j.cois.2014.06.004

Whittaker, R. & Fernández-Palacios, J. 1998. Island Biogeography. Ecology, Evolution, and Conservation. Oxford University Press, Oxford. 285 pp